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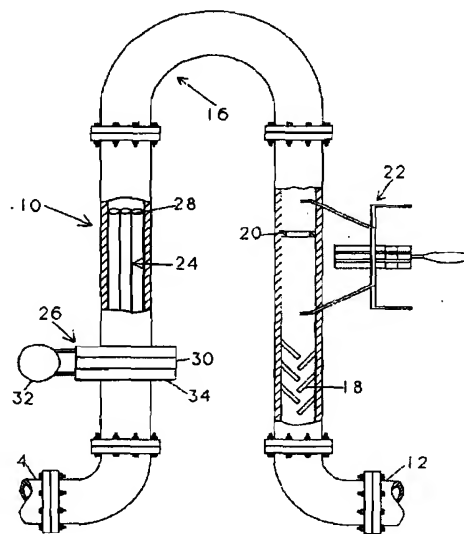
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(54) **Multi-phase fluid flow monitor and method**

(57) A monitor (22) obtains signals representative of the gas, oil and water fractions in a multi-phase flow and thereby a density signal representative of the fluid mixture density. A flow meter (26) senses the pressure differential across an orifice plate (30) and provides a fluid flow rate signal in accordance with the pressure differential and the fluid density. Individual gas, water and oil volumetric flow rate signals can thereby be obtained.



**EP 0 690 292 A2**

## Description

This invention relates to methods and apparatus for obtaining a measure of the volumetric flow rate of gas in a multi-phase fluid mixture flow comprising gas, oil and water, and optionally also measures of the volumetric flow rate of the water and the oil.

There are a great many applications where a three phase flow meter, which does not require separation of the fluids, will be of significant economic value. Gas (and therefore three-phase flow) is present to some extent in virtually all live crude oil handling operations. Particular problems can arise in some situations, such as in off-shore, unmanned, primary wellhead production situations where no gas is expected initially. Gas will eventually be produced due to pipeline pressure drops and with aging of the reservoir. It is important to monitor the production of this gas as well as the rate of increase in gas production.

The present invention utilizes a water cut monitor capable of measuring gas fraction, as well as liquid water-to-oil ratio, in combination with a flow metering device, such as an orifice plate and a differential pressure meter. A suitable water cut monitor for use in the subject system is the TEXACO STARCUT® monitor. The subject system preferably also includes appropriate static flow mixing means upstream of the water cut monitor and flow straightening means upstream of the flow metering device.

The present invention will now be described, by way of example, with reference to the accompanying drawings, in which the single figure is a schematic diagram of a low gas embodiment of a water cut monitor system according to the present invention.

The subject water cut monitor is used in combination, either in series or in parallel, with a flow metering device designed to be used with a single phase fluid, such as water, oil or gas. The single phase meter may be any known flow meter which will function better if the composition of the mixture passing through the meter is known. The present invention will be discussed, by way of example, using a TEXACO STARCUT® monitor and a flow metering device of the type having an orifice plate and a differential pressure meter. The particular example illustrated is a series connected low gas system with appropriate fluid mixing and flow straightening appropriately included. The present invention is suitable for use in either high or low gas situations.

Turning now to the Figure, the subject system 10 is connected between inlet pipe 12 and outlet pipe 14 and generally comprises an inverted U shaped pipe 16. A static mixer 18 is fixed in one leg of pipe 16 adjacent the inlet pipe 12 and an orifice plate 20 is spaced downstream of the mixer. A water cut monitor 22 of known design is connected across the orifice plate 20, the purpose of which is to create a pressure drop forcing fluid to flow through the water cut monitor. A flow straightener 24 and a differential flow meter 26 are fixed in the other

leg of pipe 16. The flow straightener 24 can be an assembly of straight pipes 28. The flow meter 26 comprises an orifice plate 30 and a differential pressure meter 32 spanning the orifice plate 30.

The output of the water cut monitor 22 provides water fraction, oil fraction and gas fraction of the fluids about to pass through the flow metering device 26. In the present instance the water cut monitor 22 uses fraction data which allows computation of the average density of the fluid mixture passing through the flow meter 26. In the present example the flow meter 26 is a known orifice meter consisting of a pipe line flow tube and an orifice plate 30 mounted in a Daniels Simplex junior plate holder 34, such as manufactured by Daniels Industry. The differential pressure across the orifice plate is monitored using a known differential pressure meter 32.

The standard orifice plate equation is:

$$\text{Volumetric Flow rate} = K \cdot \frac{(\rho \cdot d_p)^{5/2}}{\rho}$$

where:

K is a constant obtained from standard tables and equations;

$\rho$  is the density of the fluid passing through the orifice; and

$d_p$  is the differential pressure across the orifice plate (measured just upstream and just downstream of the plate).

The monitor provides  $X_g$  (the gas fraction),  $X_o$  (the oil fraction) and  $X_w$  (the water fraction) where:

$X_g + X_o + X_w = 1.0$  and the fluid mixture density in the monitor is then

$$\rho = X_g \cdot \rho_{gas} + X_o \cdot \rho_{oil} + X_w \cdot \rho_{water}$$

where:

$\rho_{gas}$  is the gas density;

$\rho_{oil}$  is the oil density; and

$\rho_{water}$  is the water density.

In practice the differential pressure meter 32 provides a current loop (4-20 ma) carrying the differential pressure information which is automatically read by the monitor (not shown) and included with its internally calculated fractions as listed above.

The volumetric flow rate of each component is then computed by multiplying the net volumetric flow rate, (equation above) by the fluid fraction, for example

$$Q_{gas} = Q_v \cdot X_g$$

$$Q_{oil} = Q_v \cdot X_o$$

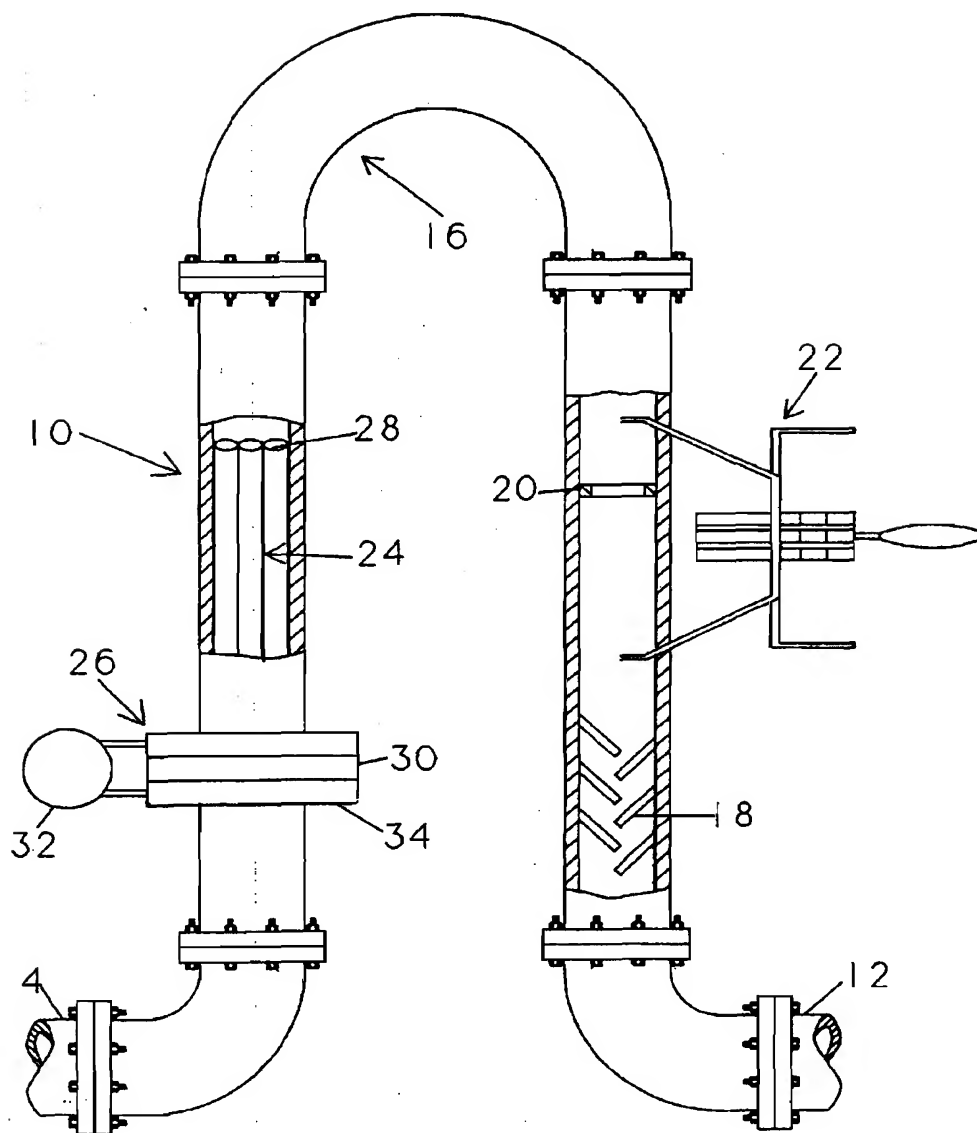
$$Q_{water} = Q_v \cdot X_w$$

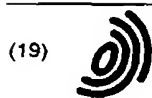
The accuracy of the instrument is greatly enhanced if the fluids are well mixed and the relative velocity of the individual components are approximately the same. This instrument is thus recommended for use in low gas situations, defined as gas less than 20% by volume at the pressure of the measurement.

The present invention may be subject to many modifications and changes which will be apparent to those skilled in the art. The present embodiment is therefore to be considered in all respects as illustrative and not restrictive of the scope of the invention as defined by the appended claims.

#### Claims

1. A method of obtaining a measure of the volumetric flow rate of gas in a multi-phase fluid mixture flow comprising gas, oil and water;  
characterized by:  
providing monitoring means to obtain fraction signals ( $X_g$ ,  $X_o$ ,  $X_w$ ) representative respectively of the gas, oil and water fractions in said flow;  
obtaining a density signal ( $\rho$ ) representative of the fluid mixture density in accordance with said fraction signals;  
providing a flow meter operable to sense a pressure differential ( $d_p$ ) in said flow and to provide a flow rate signal ( $Q_v$ ) representative of the volumetric flow rate of the fluid in accordance with the sensed pressure differential and said fluid density signal; and  
obtaining a gas flow signal ( $Q_{gas}$ ) representative of the volumetric flow rate of the gas in said fluid flow in accordance with said gas fraction signal ( $X_g$ ) and said flow rate signal ( $Q_v$ );
2. A method according to Claim 1 further characterized by obtaining an oil flow signal ( $Q_{oil}$ ) representative of the volumetric flow rate of the oil in said fluid flow in accordance with said oil fraction signal ( $X_o$ ) and said flow rate signal ( $Q_v$ ).
3. A method according to Claim 1 or Claim 2 further characterized by obtaining a water flow signal ( $Q_{water}$ ) representative of the volumetric flow rate of the water in said fluid flow in accordance with said water fraction signal ( $X_w$ ) and said flow rate signal ( $Q_v$ ).
4. A method according to any one of Claims 1 to 3 characterized in that said flow meter comprises an orifice plate and a differential pressure meter disposed to sense the differential pressure in the fluid across said orifice plate, said flow meter providing a pressure signal ( $d_p$ ) representative of the sensed differential pressure across said orifice plate.
5. A method according to any one of Claims 1 to 4 characterized by providing said monitoring means and said flow meter in series along a fluid flow line.
6. Apparatus for obtaining a measure of the volumetric flow rate of gas in a multi-phase fluid mixture flow comprising gas, oil and water;  
characterized by:  
monitoring means (22) operable to obtain fraction signals ( $X_g$ ,  $X_o$ ,  $X_w$ ) representative respectively of the gas, oil and water fractions in said flow, and to provide a density signal ( $\rho$ ) representative of the fluid mixture density in accordance with said fraction signals;  
a flow meter (26) operable to sense a pressure differential ( $d_p$ ) in said flow and to provide a flow rate signal ( $Q_v$ ) representative of the volumetric flow rate of the fluid in accordance with the sensed pressure differential and said fluid density signal; and  
means for obtaining a gas flow signal ( $Q_{gas}$ ) representative of the volumetric flow rate of the gas in said fluid flow in accordance with said gas fraction signal ( $X_g$ ) and said flow rate signal ( $Q_v$ ).
7. Apparatus according to Claim 6 characterized by means for obtaining an oil flow signal ( $Q_{oil}$ ) representative of the volumetric flow rate of the oil in said fluid flow in accordance with said oil fraction signal ( $X_o$ ) and said flow rate signal ( $Q_v$ ).
8. Apparatus according to Claim 6 or Claim 7 characterized by means for obtaining a water flow signal ( $Q_{water}$ ) representative of the volumetric flow rate of the water in said fluid flow in accordance with said water fraction signal ( $X_w$ ) and said flow rate signal ( $Q_v$ ).
9. Apparatus according to any one of Claims 6 to 8 characterized in that said flow meter (26) comprises an orifice plate (30) and a differential pressure meter (32) disposed to sense the differential pressure in the fluid across said orifice plate, said flow meter being operable to provide a pressure signal ( $d_p$ ) representative of the sensed differential pressure across said orifice plate.
10. Apparatus according to any one of Claims 6 to 9 characterized in that said monitoring means (22) and said flow meter (26) are provided in series in a fluid flow line.





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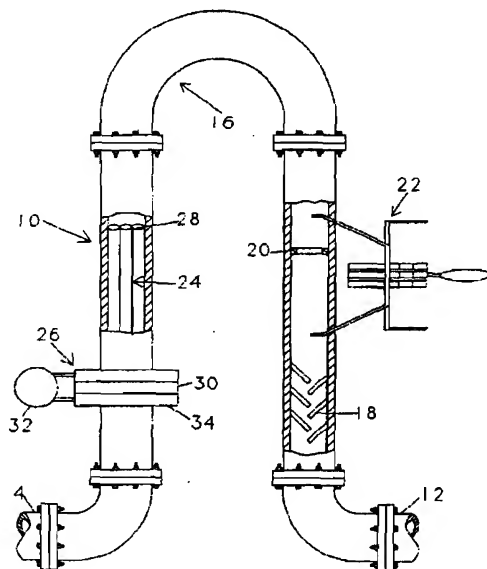
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## EUROPEAN SEARCH REPORT

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EP 95 30 4450

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.CL6)
A	EP 0 493 886 A (TEXACO DEVELOPMENT CORP) 8 July 1992 * column 2, line 1 - column 3, line 34; figure *	1,6	G01F1/74 G01F1/36
A	GB 2 266 597 A (PECO PRODUCTION TECHNOLOGY LIM) 3 November 1993 * claim 1 *	1,6	
			TECHNICAL FIELDS SEARCHED (Int.C.4)
			G01F
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 3 September 1997	Examiner Heinsius, R
<b>CATEGORY OF CITED DOCUMENTS</b> X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure F : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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